NUMERICAL ANALYSIS OF THE BEHAVIOR OF PRECAST L-SHAPED BEAMS

By
Ahmed Mostafa Elsaied Ali Ghanem

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
In
Structural Engineering

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Under the Supervision of

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Thesis Title:

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Keywords:
Nonlinear analysis, finite element, skew bending failure, precast beams, prestressed beams

Summary:
Precast spandrel L-shaped beams are commonly used in the perimeter of precast parking structures to transfer deck loads to vertical members. The unsymmetrical cross section of these beams which supports eccentric loads resulting in combined shear, torsion and flexure forces makes spandrel L-shaped beams one of the most critical elements in precast construction. These loading conditions forces the spandrel beams to significantly rotate about its weak axis. This lateral deflection increases as loads increase that may cause instability of the beam. Therefore, limiting this lateral deflection has become the subject of many studies for these types of beams. The main challenges facing L-shaped beams are shear and torsion distress in their end regions near supports where they experience a skew bending failure. The objective of this research is to study the behavior of these beams under combined loading conditions. Testing full scale spandrel beams with their large cross section was believed to be costly. Therefore, this research introduces a parametric study including 16 finite element models to investigate the effect of various factors believed to influence the behavior of these types of beams. Moreover, this research introduces new proposed special connections that reduce the rotation of spandrel L-shaped beams. Results of the parametric study are encouraging to reduce the lateral deflection of the spandrels to minimum.

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To my wife and son, thank you for lighting my way. Your smile always pacifies any worries. I am so lucky to have you.

Dedication

To my parents, I wish I made you proud.

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Abstract

Precast spandrel L-shaped beams are simply supported on column corbels, commonly used in the perimeter of precast parking structures to transfer deck loads to vertical members. The ledge runs along the bottom edge of the beam forming L-shaped beam. Transferring vertical loads through the ledge to the beam results in eccentric loads on the slender cross section which needs complicated reinforcement details. The spandrel L-shaped beams are supported laterally by the column at the top and bottom of the web ends which help in preventing rotation of the beam ends about its longitudinal axis. The unsymmetrical cross section of these beams which supports eccentric loads resulting in combined shear, torsion and flexure loads makes spandrel L-shaped beams one of the most critical elements in precast construction. These loading conditions forces the spandrel beams to significantly rotate about its weak axis. This lateral deflection increases as loads increase that may cause instability of the beam. As a result, limiting this lateral deflection has become the subject of many studies for these types of beams. The main challenges facing L-shaped beams are shear and torsion distress in their end regions near supports where they experience a skew bending failure. These spandrels commonly connected to deck sections via welded connections to act as lateral support along its span. The objective of this research is to study the behavior of these beams under combined loading conditions.

Testing full scale spandrel beams with their large cross section was believed to be costly. Therefore, this research introduces a parametric study including 16 finite element models to investigate the effect of various factors believed to influence the behavior of these types of beams. Moreover, this research introduces new proposed special connections that almost reduce rotation of spandrel L-shaped beams to minimum. Numerical models were calibrated with experimental results and then used to investigate the targeted parameters. Results of the parametric study are encouraging and promising to mostly reduce the lateral deflection of the spandrels to minimum.

CHAPTER 1: Introduction

1.1 Problem Definition

Precast concrete spandrel slender L-shaped beams are commonly used at the perimeter of precast parking structures. Spandrel L-shaped beams are simply supported on column corbels to support vertical loads from deck members. The typical section used for deck members in parking structures is double tee slab. Typically, the ledge runs along the bottom edge of the beam on one side to form the L-shaped beam. The unsymmetrical section of the beam supporting eccentric loads from the stems of the double tee slabs forces the beam to deflect vertically and laterally along with significant rotation. Due to the above conditions, Spandrel L-shaped beams are considered one of the most complex elements in the precast industry. Common span and depth of the spandrel beams ranges from 9 to 15 m and 1.2 to 2.5 m respectively. Consequently, the spandrel beams are subjected to relatively high shear, torsion and bending moments. The high applied loads result in complex reinforcement and congested closed stirrups required by the complex structural behavior of the spandrel beams. It has been well documented that the failure mode of the slender spandrel L-shaped beams is skew bending failure as discussed in the literature review. The failure mode indicates diagonal flexural shear crack due to combined shear and torsion after a significant lateral deflection and rotation. This lateral deflection increases as loads increase that cause instability of the beam. Limiting lateral deflection and rotation of the slender spandrel beams may enhance the whole behavior of the beam. Testing full scale spandrel beams with their large cross section was believed to be costly. For this regard, Finite element modeling was found to be a suitable way to investigate various parameters that affect the behavior of the beam along with proposing new arrangement for lateral supports that enhance the beam's behavior.

1.1 Objectives

The main objective of this research is to study the effect of various parameters on the behavior of precast slender L-shaped beam. These parameters are important to be investigated to be used to enhance beam capacity and behavior against the eccentric loading applied along its ledge. Moreover, New proposed arrangements of deck ties are presented in order to minimize the rotation of the beam.

1.2 Scope

To the achieve the objective of the research, the scope of the research program included the following:

1. An intensive literature review of the development of L-shaped beam investigation and design. The review included the main characteristics of the beam and most of published reports of field observations, experimental works and analytical studies.
2. Calibration of 3-D nonlinear finite element model using available experimental data to ensure the capability of the finite element program to predict reasonable and acceptable results.
3. Developing nonlinear finite element models to investigate the effect of various parameters believed to affect the behavior of these types of beams.
4. Analysis of the parametric study results and presenting recommendations.

1.3 Thesis Overview

Following problem definition, objectives, scope and thesis overview presented in this chapter, Chapter two refers to a comprehensive literature review about the development if the design of precast L-shaped slender beam. The literature review includes published studies and field observations that describe the main challenges L-shaped beams are facing.

Chapter 3 presents the calibration process of three-dimensional nonlinear finite element model using available experimental results. In this chapter, brief explanation of how the finite element program deals with nonlinearity along with mentioning specific factors believed to affect the predicted results.

Chapter 4 introduces the parametric study investigated in this thesis, where materials and loads used for all models are mentioned in the first pages of the chapter. A brief explanation of each chosen parameter and its influence on the behavior of beam is presented along with well-organized figures and results showing how the beam reacted under each condition.

Chapter 5 comes with the summary of the thesis, conclusions conducted from analyzing parametric study results and recommendations for future work.